Economic Uses of Lichens

Some of these lowly plants have long served as fodder for the reindeer herds of Lapplanders, while others have been the sources of industrial dyes, as those used in the manufacture of Harris Tweed cloth.

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Introduction

THIS article is a general discussion of most of the economic uses of lichens. A more detailed account, including the biology of lichens, was published by the present author (13) in 1944, of which this treatment is a revision of the economic uses only. Neither of these papers is complete but merely an attempt to bring together some of the information regarding utilization of lichens, and a working bibliography for those who have little familiarity with lichenology. None of this material is available in text-form; most general texts mention lichens in the most perfunctory manner, citing references only from older texts which give little credit to modern studies.

Though other branches of the botanical sciences have received considerable impetus from the activities of research in recent years, little of this force has carried over into the science of lichenology. Lichenology is not a popular study. It is reserved to a few specialists throughout the world whose studies are largely in the realm of lichen taxonomy, geography and ecology. To the few who have investigated the chemical and physical as well as physiological structure of lichens, all lichenologists owe much for the stimulation which they have given to the science. Among these recent contributions attention should be directed especially to that of Quispel (14).

Biology of Lichens

Lichens can be distinguished by their habit of growth as crustaceous, fruticose or foliose. The first form is the most simple, on bark, wood, rocks or soil; the other two forms are more intricate, often erect, branched or leaf-like, usually with a dorsal and a ventral surface but in some species merely circular. These plants are widely distributed from the arctic to the tropics, consisting of thousands of species and innumerable varieties and forms. They have one feature in common that distinguishes them from all other plants. Each of them consists of two different and separate entities living together in such a balanced relationship that they not only form a successful organism but are able to reproduce the unit. One component is a fungus, usually an Ascomycete but in a few cases a Basidiomycete, whose intertwining, compact hyphae give form to the thallus. The other component consists of a species of green or blue-green alga enmeshed between the hyphal strands of the fungus. In this combination, each component is able to extend its activities into habitats that would be inimical to it as an independent organism. Together they form a particular species of lichen with specific morphological, taxonomic, ecologic and sometimes physiologic characteristics, the fungal part growing by extension of its hyphae, the algal cells by division of themselves.

This intimate relation of fungi and algae is usually regarded as one of symbiosis, *i.e.*, of mutual benefit to each component, the fungal element deriving food from the green algae, and the algae benefitting by having its moisture and mineral nutrition maintained through the water absorption and water retention characters of the fungus. The presence of fungal haustoria, however, and the penetration of hyphae into the algae have been cited as evidence that this relationship is merely another case of parasitism; the algae can live independently but the fungi can not.

The morphology of the reproductive system is the chief basis of all taxonomic treatments of this group with the inevitable result that many mycologists have segregated the various groups among those fungi that appear to have a close relationship. However, the thallus is a specialized type of structure, and the fungus-alga relationship makes possible specialized functional relationships peculiar only to lichens. They may be conveniently treated as a homogeneous group, for they have their own literature and specialists who concentrate their studies wholly on them.

The fungal components of lichens reproduce sexually by means of ascospores, or basidiospores, depending on the type of fungus-symbiont present. When these spores germinate, however, growth cannot continue unless the resulting hypha happens to come in contact with the particular species of alga necessary for its development into the kind of lichen from which it arose. A more common method of propagation, and perhaps the more successful, is asexual. This may be merely by broken pieces of the thallus body being blown or carried elsewhere, or by detachment of a minute mass of hyphae enclosing algal cells from specialized structures known as "soredia"; this secondary method of reproduction is not found in all species of lichens. Lichens have been synthesized in a few cases by bringing together the two component parts.

Mosses are often mistaken for lichens. The two should never be confused, however, for mosses possess a stem and leaves which are never found in lichens. On Pacific Coast trees there may be found *Ramalina reticulata,* a lichen of great beauty, often called "Spanish Moss" from its pendant habit of growth. This term "Spanish Moss" is more often used commonly for similar hanging plants on the trees of the southern States, though here, again, in error, for those plants are not mosses but members of a seed-bearing plant family, the Bromeliaceae.

Lichens as Food for Invertebrates

Certain studies (19) concerning invertebrates known to feed partly or wholly on lichens include the feeding habits of mites, caterpillars, earwigs, black termites, snails and slugs. Invertebrates apparently feed on all but the most gelatinous lichens which have almost complete immunity because of their slimy covering. Dry hard lichens are rarely attacked, although it has been noted that two species of snail graze on the endolithic lichens *Verrucaria* and *Protoblastenia,* mainly on the thalli and the apothecia. Excrement from these snails contained fragments of calcium carbonate and green algal cells, while the hyphae and dead algal cells were apparently digested. Experiments have shown that snails will feed on potatoes covered with cetraric, rhizocarpic and pinastrinic acids, poisonous to other animals, but will not feed on vulpinic acid which is recognized as poisonous to vertebrates. Bitter-tasting lichens, treated by a soda method to extract the acids, were acceptable in preference to fresh untreated but moistened lichens. This is of interest, since there is a widely current assumption that lichens are remarkably well protected against attacks from animals by reason of these acids.

Free living algae are the preferred food of invertebrates, in most cases, but when not obtainable, the gonidia, *i.e.*, the algal layers in the lichen thallus, are taken. Hué (13)[1] presented the opinion that the abundance of lichens in Arctic regions results from the comparative absence there of snails and insects. Not a few "new" species of lichens have been the result of insect and snail ravages, further modified by plant regeneration.

Lichens Used as Fodder

Non-grassy Ranges. This subtitle refers specifically to range lands which are composed primarily of lichens or which are used at definite times of the year for grazing because of the lichen vegetation. Such areas are rarely entirely free of sedges, grasses, herbaceous plants, low bushes and sphagnum bogs. When this type of vegetation is at its best in spring and summer, it has little value as non-grassy range land. These areas lie north of the tree line and above timber line but may extend well down into the timber along mountain sides. They are best developed in sub-Arctic regions but may extend into the temperate zones. They cover those parts of Greenland which are ice-free and still have sufficient moisture for plant growth, Iceland, northern Scandinavia, Siberia, Alaska, the Northwest Territories of Canada, Labrador and the archipelago of the Arctic Sea. As a whole, the thousands of square miles composing this area furnish non-grassy range feed in the winter for wood buffalo, musk-ox, caribou and other wild herbivores and for domesticated reindeer, as well as a grassy range feed at all other times. It is not to be assumed from this statement that all these wild species of animal are entirely dependent on lichen forage for winter grazing. Actually, too little is known of their food preferences to permit a definite statement.

In the Antarctic regions, though lichens are the predominant plants, they are not so richly developed as in the Arctic. Due to absence of herbivores in this area, further discussion of it will be omitted. The extreme southern part of South America, Tierra del Fuego and lower Patagonia might also be included in this classification. Santesson of Uppsala, Sweden, has related to the author that when he was botanizing in the Argentine during the late war, he was approached by government officials requesting advice on the practicability of importing reindeer into those regions for the use of the natives. Santesson's opinion, based on his thorough knowledge of lichen species and of reindeer culture, indicated that the South American lichen species of the area under consideration, although probably acceptable to reindeer, were not abundant enough to sustain them. A news report of Oct. 20, 1947, however, stated that 20 reindeer have been imported into Argentina for stocking the Tierra del Fuego area. These are to provide food, clothing and transportation to the 3,513 inhabitants of the archipelago, and are part of the Plan Quiquenal "which will make Tierro del Fuego a magnificent exponent of social and economic progress. . .".

Reindeer have been introduced, apparently with some success, for the more stable support of Eskimos in Alaska and northern Canada and also as straight commercial ventures. This emphasizes the value of non-grassy ranges. A report of 1929 by the United States Department of Agriculture in Alaska states that there already is danger of over-grazing

[1] Citations in the present author's original article (13) are not repeated in the bibliography of the present article but are to be found in the former.

in those areas where reindeer have been introduced. This is a problem that the Lapp herders recognize and meet by keeping their herds on the move during the critical winter period. Reindeer require constant care and the use of knowledge which is a basic part of the old Lapp culture. If the Eskimos are capable of assuming this responsibility and of applying to these animals the principles which they may have observed in caribou, an experiment of this kind is sure of some success. The caribou and the old world reindeer have similar habits, feeding on lichens in snow-free areas or pawing away the snow cover to obtain better grazing. In summer they migrate into the highlands, partly to avoid insect pests and partly to feed in fresh pastures. The constant movements of caribou during the winter period throughout their range and during the spring and summer from the lowlands to the highlands prevent overgrazing in any one part of the feeding range.

Lapp culture is primarily a reindeer culture, so specialized in its application that the Lapps have derived their own Lapponian terms for varying types of reindeer grazing lands and lichen species which they differentiate sharply, no mean feat in itself. The living problems of present day Lapps arise mainly from the fact that some of them have given up their nomadic habits and hence their main source of revenue, reindeer herds. The Norwegian, Swedish and Finnish governments are conscious of their responsibilities toward these people and of the importance of helping them maintain their culture, and so they encourage lichenologists to make studies and surveys of the lichen flora in those countries.

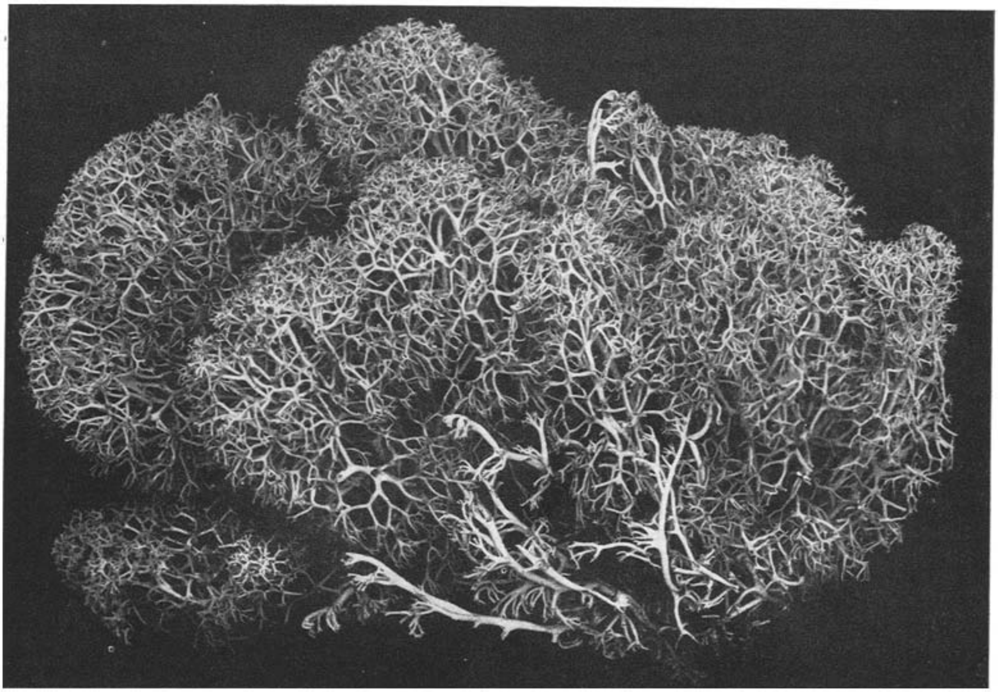


FIG. 1. Reindeer moss, *Cladonia alpestris*. This species and *Cl. rangiferina* constitute the principal food of reindeer and caribou herds. (*Courtesy The New York Botanical Garden.*)

Reindeer have a market value of from

200 to 300 Swedish Kroner (3.60 sw. kr.= $1.00, Aug. 1947), and it is not unusual for a Lapp to possess several thousand animals; such a person can hardly be considered indigent. Reindeer meat is unrationed and is served throughout Fennoscandia. The hide is used for leather goods and, with the hair, is manufactured into footwear and a high quality sleeping bag. During the war German troops stationed in Finmarken slaughtered reindeer indiscriminately for meat and hides.

Reindeer culture is not peculiar to the Lapps but prevails also among other nomadic tribes inhabiting lands bordering the Arctic Sea from Murmansk across and down into Siberia. This is partly indicated in a study (8) on the chemistry of under snow fodder for winter pastures of reindeer in the U.S.S.R. The United States Government and the Canadian Government have embarked upon a program of wholesale importation of reindeer into northern areas without consulting or encouraging lichenological studies or surveys as a basis for selecting non-grassy range lands for the highest relative pasture capacity. The possibilities for survival on northern submarginal lands is greatly enhanced by the proper use of these lands for reindeer grazing.

The most useful species for grazing are the so-called reindeer lichens, *Cladonia rangiferina* Web., *Cl. alpestris* Rabenh. and *Cl. sylvatica* Hoffm., though the last is sometimes said to be refused by reindeer. Probably others, *e.g.,* species of *Cetraria, Stereocaulon* and *Alectoria,* are accidentally or preferably taken, since they are found growing with the former. The Cladoniaceae are the most important, for they grow in carpet-like masses to a height of six inches. Their dependence on the substratum is not clearly recognized, since they grow almost equally well on all available areas, especially after fire, competing with and preventing the development of certain seedlings. They may be covered for long periods by snow, but the animals that are accustomed to feed on them are capable of finding them under snow cover. The use of lichens. as accessory fodder has always received attention in northern Europe in times of forage (wild or cultivated hay, grain, *etc.*) scarcity, and in some regions the plants are regularly used for this purpose.

Lynge (13) presents his own and other investigations concerning the food value, harvesting methods and growing habits of lichens in relation to the feeding habits of reindeer and cattle. He states that in 1916 the large lichen fields of Finmarken maintained 100,000 head of reindeer, resulting in a serious overgrazing problem. Smaller fields in other Norwegian provinces supported 50,000 of these animals. To remedy these conditions, regulations prohibiting reindeer pasturing were put into effect where necessary until good growth was reëstablished. Under conditions of unrestricted grazing, lichen vegetation may be seriously altered, while mere trampling by large herds in small areas will destroy these plants. Under such a situation fields of *Cl. alpestris* may be invaded by less desirable *Stereocaulon paschale* Fr. which produces full grown thalli in five to six years after which *Cl. alpestris* again becomes dominant.

In Lynge's account there is a list of Lapponian lichen terms indicative of some of the peculiarities connected with reindeer husbandry. The Lapps differentiate between lichens and mosses, since reindeer never feed on the latter. "Jaegel" refers to field lichens on which reindeer fatten; "Gadna" occurs on stones and trees and are eaten if no other food is available; "Lappo" are the beard forms growing on trees for which the animals have great fondness. The Swedish government permits the Lapps to cut down birches in winter emergen-

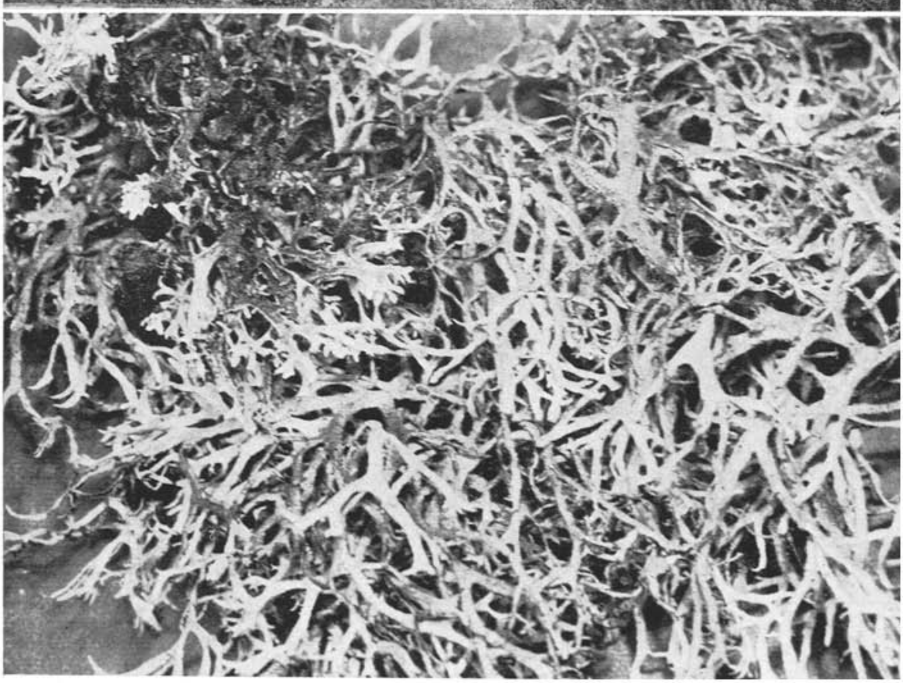


FIG. 2 (*Upper*). Rock tripe, *Umbilicaria papulosa,* with pustules on its upper surface, and two other species of *Umbilicaria* on the rock. Mt. Desert Island, Maine, U.S.A. This and other kinds of rock tripe, *Gyrophora* sp., have been used by polar explorers as emergency food.

FIG. 3 (*Lower*). *Evernia furfuracea,* showing upper and lower surfaces of the thallus. Mt. Desert Island, Maine, U.S.A.

cies to enable the reindeer to get at this type of feed. The herders also recognize the pasture cycle after fire with its successive lichen formations. Reindeer feed on the younger parts or tips of the plants.

The relative abundance of these economic lichens would be best stated as "generally common", for solid areas of any one species is the exception rather than the rule. *Cetraria islandica* Ach. in average areas yields about 700 kilo of air-dried "moss" per sq. km. *Cl. alpestris* gives higher yields, and selected areas in northern Norway have produced 1,400 to 1,500 kilo per 1,000 sq. m.

Harvesting is performed by hand or hand implements; this is for the use of domestic animals only, for even the Lapps keep goats or a cow in addition to their reindeer. Among the Lapps the work is performed by the women and by hand, a method considered conserving and cheap, since only a quarter of the quantity growing is thus garnered, leaving enough for regeneration. The Norwegian method, using rakes with 15 cm. teeth, takes up to two-thirds of the amount available. Sticks are shaken out, and the adhering soil may be separated by water. Dry "moss" is brittle and to avoid large losses is most economical when having a water content of 40 to 70% by weight. As the plant is gathered it is piled into small heaps (40 to 50 cm. high) with a branch of birch in the center for a handle. These small heaps are brought together to form large bundles. They are moved around on sunny days in the field when the water content may go down from 60% to 30%, and are then placed in straw-covered shelters. Otherwise they are taken to a drying house in winter in sledge loads of from 300 to 600 kilo. The crop may be further dried in a warm ventilated room and stored when the water content has gone down to 14% of the dried weight. Hand presses are unpopular because of their cost and weight. Transportation costs for this type of forage is considered expensive, and the forage is never transported far.

One cause for occasional friction between the Lapps and the Scandinavians in these northern areas is the more thorough harvesting methods of the latter which have caused the Lapps to complain of loss of grazing areas. Reindeer crop the lichen close but leave enough of the thallus for future growth and the possibilities that the area can be pastured again within four years. Hand harvesting or implement harvesting uproots the lichen thallus, and it may take ten or more years for regeneration and growth. This situation has been alleviated by regulations imposed by the local governments. Lichens on trees may be scraped away and gathered in sacks by non-Lapps.

A farmer having ten cows and some sheep and goats uses yearly 60 sledge loads of lichens for his stock. This implies a need of 4,800 to 18,000 sq. m. of well covered lichen fields per year. Since these plants may require up to 30 years to regenerate a marketable stand, a farmer must have access to 150,000 to 560,000 sq. m. of land. This land must be preferably mountain or heath land, since forest areas contain objectionable pine needles and sticks. However, few farmers give so much lichen fodder to their cattle, actual amounts depending on the quantity of grass available. In "moss" districts three to five sledge loads are collected per cow. It is possible for one man to gather from 50 to 100 kilo. by hand per day or with implements to increase this up to 300 to 400 kilo. per day. Even in older times it was difficult to get laborers for gathering lichen fodder, due to the small pay, and it was necessary for the State to intervene. School classes were encouraged to collect, receiving three ore per kilo per student and one ore per kilo for the teacher (4).

As an additional food for domestic animals, especially swine, lichens are of value, and Lynge recommends greater use of svinamöse (swine-moss) for these animals. Jacobj (13) found that young pigs throve better on a combination of reindeer moss and ordinary feed than with the latter alone. He also satisfactorily fed rabbits and hares with *Evernia prunastri* Ach. after extracting the acids. Icelanders feed *Cetraria islandica* to their cattle, pigs, and ponies. It has also been reported good for oxen, while the richness of the milk of the small cows of northern Scandinavia is attributed to this food. An early traveller relates that during a period of famine in Finmarken, the farmers preferred to feed *Cetrara islandica* to their cattle than to use the lichen themselves for food but risk the loss of their cattle. Cows were given 10 kilo, horses 6 to 8 kilo, swine 2 to 3 kilo, and sheep and goats 1 to 2 kilo daily (4).

FIG. 4. Reindeer, summer-feeding in Lappland, Sweden. (*Courtesy Swedish Railways*).

Nutritional Studies. The nutritive value of these non-grassy range feeds apparently lies in their high lichenin (lichen starch) content. Hesse (13) worked out a comparison of the sugar content of lichens with that of potatoes and found that for *Cetraria islandica* the proportion was 1 of potatoes to 3.35 of lichen; for *Cl. rangiferina*, 1:2.5. The former has been found to yield 61% carbohydrates and other products of its hemicelluloses. The bitter principle, due to the presence of lichen acids in even the mildest of these plants, can be removed in order to make the fodder more palatable to domestic animals. This is done by soaking them in water for 24 hours or by addition of potassium carbonate to the water for quicker action. Boiling with lye, after which the lichens are thoroughly rinsed with water, is the usual method of preparing the plant for human animal consumption. Sometimes the lichens are mixed with hot water and straw or meal, and salted before being fed to cattle; the proportion of meal and salt is gradually reduced until the cattle become accustomed to the lichen alone. One kilo of *Cl. rangiferina* (15 to 18% water content) is considered to be equal to one third poor fodder or early grass. By analysis this lichen is found to contain 1 to 5% proteins, the rest carbohydrates and little or no albumen(4).

Russian investigations of the under-snow fodder from winter pastures at the Saranpaul State Reindeer Farm indicate that winter herbage is rich in crude fats and in nitrogen-free extracts, and that the content of fiber and hemicellulose is higher in winter than in summer herbage. Chemical study of winter and summer lichen herbage showed a higher protein than fat content, particularly in *Alectoria jubata* Ach. (7.77%) and *Umbilicaria pennsylvanica* (6.27%) which varied with the season(4).

Use of lichen fodder in Europe goes back into antiquity, as indicated by prehistoric remains found near Lake Constance in Switzerland (19).

Lichens Used as Food by Man

History. From the earliest times the food of man has included lichens, sometimes as a delicacy, but more often as a last resort in the face of starvation. Their commercial importance however, as food for man, has decreased, though Hanstien, chief lecturer in the Agricultural School at Aas, Norway, long ago prophesied that lichens are destined to become the great popular food for the masses because of their cheapness and nutritive value. The use of lichens for human food has been revived at times, and they were recommended in Sweden as substitute food in 1826, 1841 and 1868 after bad frosts and droughts had affected regular crops. In general, the bitter principle in these plants gives them an unpleasant flavor, and unless removed, exerts an irritating effect upon the digestive tract of man, causing inflammation.

Cetraria islandica probably rates first as lichen food for humans. It is gathered commercially in the Scandinavian countries and in Iceland and sold on the market as "Iceland Moss". Schneider says of this "moss": "Inhabitants of Iceland, Norway and Sweden mix this with various cereals and mashed potatoes from which an uncommonly healthful bread was prepared". Lynge (13) quotes a tradition "that there was no starvation at Modun in 1812 as long as there was brodmöse (bread-moss) left in the forest". Icelanders made the most of lichens as food for humans, collecting great masses of this plant yearly. Two barrels of clean lichens pressed down gave the equivalent of one barrel of the usual grain meal. From this flour they made bread, gruel, porridge, salads and jelly in various ways. Milk was added, and in this form the lichen was the basis of various light and easily digested soups and other delicacies said to be of value for dyspeptics. It was also mixed with flour in making a non-friable ship's bread which was less subject to weevil attack than ordinary bread. In northern Finland, in times of famine, reindeer moss and rye grain were made into a bread having a taste like that of wheat bran but leaving a sense of heat on the tongue.

Before use the lichen was boiled with lye, rinsed in clear water, dried and placed in closed containers which were stored in a dry place. In this fashion it would keep for many years. For breadmaking it was first oven-dried, then ground fine; one fourth grain meal was next added, and the mixture was baked as usual, producing a strong bread with a fair taste which kept well in storage. *Cetraria islandica* was also mixed with elm cortex as well as with grain and boiled with a surplus of water to produce a broth. *Cetraria nivalis* was occasionally used in the same manner. For porridge, a cooking container was filled with one third *C. islandica* and boiled with water three or four times, stirring frequently until it became thick. The top broth and scum were skimmed off and the rest salted according to taste. This was permitted to cool until hard, then eaten with or without milk. It could be redried in an oven and used for bread. As gruel, about one pound of the finely cut lichen was added to one and a half to two quarts of water and cooked slowly until about one half of the water had been evaporated. This was strained while hot and flavored with raisins or cinnamon. After boiling, and separating the broth, the residue was eaten with oil, yellow of egg, sugar, *etc.*, as a salad, "and the most pretentious person will like it". The hardened jelly of this lichen was often mixed with lemon juice, sugar, chocolate, almonds, *etc.* (4).

The biblical manna of the Israelites appears to have been *Lecanora esculenta* Evers. (19) which is still eaten by desert tribes, being mixed with meal to one-third of its weight. This lichen grows in the mountainous regions and is blown loose into the lowlands where the thalli pile up in small hummocks in the valley. As late as 1891 there was an abundant fall of this "manna" in Turkey. The Turks are recorded as using *Evernia prunastri* for jelly (4); the ancient Egyptians also used this lichen and *E. furfuracea* Mann in making bread (13). There is still some importation of these lichens from Europe as fermentative agents, and Forstal in the 19th Century reported seeing several consignments from the islands of the Greek archipelago bound for Alexandria. In India (17) *Parmelia abessinica*, "Rathipuvvu", is used as food, generally in a curry powder, and medicinally; while in Japan *Umbilicaria esculenta* is considered a delicacy and sold as "iwa-take" or "rock mushroom". Because of the scarcity of collecting places and the difficulty of access, the market price is relatively high. In France lichens are used in the manufacture of chocolates and some pastries; the lichenin is, in this case, merely used as a filler and a substitute for commercial starch.

The American Indian's knowledge of wild food plants included the use of *Alectoria jubata*, though there are indications that some of the more primitive Pacific coast tribes made greater use of these plants. "Tripe de Roche" or "Rock Tripe" was so named by the French "courreur de bois" of boreal America who used it in periods of emergency. Franklin recorded it in his diary as the main course of many a meal. This "Rock Tripe" is one of the Umbilicareae and must be treated with boiling water or at least soaked before being eaten. Franklin's use of this lichen has been quoted many times, though the complete report states that the species used caused severe illness. This was probably the basis for the recommendation to personnel of the United States Army Air Forces during the war for its use under emergency conditions in Arctic areas. It may be noted that members of the Franklin Expedition were also boiling and eating the leather of their equipment. Under such starvation conditions any type of food or plant may be used in an attempt to allay hunger. But under a preplanned program designed to educate personnel with a minimum of out-of-door experience and no knowledge of plants suitable in such eventualities, a greater emphasis of the more common vascular plants and of the animals in these regions would have been more applicable towards the preservation of life. Lichens are not easily recognized, and their preparation with fire presumes the accessibility of fuel which may not always be available. Future recommendations must be based on more thorough research studies.

Nutritional Studies. Scientific investigations regarding the digestibility of lichens and the behavior of lichen substances in the body have been too few, but the evidence at hand does not agree entirely with the fact that these plants have been used extensively as foodstuffs. Analyses have shown that they contain a variety of carbohydrates of which polysaccharides are the most common, giving rise on hydration to several sugars, some cellulose, chitosan, glucosamine and inulin. Of these the only compounds directly available in intermediate metabolism are the simple monosaccharides, *i.e.,* six-carbon sugars. Polysaccharides apparently need to be split into "physiological" sugars before they become available to the body. Uhlanders and Tollens (13) noted a difference in the occurrence of characteristic carbohydrates in various lichens examined, though they all contained some lichenin. Thinking that the substances in *Cetraria islandica* and *C. nivalis* were similar, Poulsson (13) made a bread from these two species to determine their use in diabetes mellitus. Though 46 to 49% of the carbohydrates of the former species was digested, the latter species caused such intestinal disturbances that the experiment had to be discontinued. Brown (13) failed to induce glycogen formation in rabbits by feeding them lichenin obtained from *C. islandica.* Ordinarily neither amylytic enzymes nor hydrochloric acid (0.3 to 0.5%) have any noticeable effect on lichenin, while iso-lichenin is, at most, converted into a dextrin-like form without producing sugar; the action of bacteria yields acetic, propionic, butyric and lactic acids.

FIG. 5. Reindeer pawing away snow cover to obtain lichen fodder. Lappland, Sweden. (*Photo by G. Haglund*).

More recently Wallerstein (13) fed mice white bread, later replacing it with lichenin, and showed the latter to be 53 to 64% utilized. Similarly Shimizer (13), in determining the influence of some polysaccharides on the protein balance of a dog, found that they were digestible and available foodstuffs in the alimentary canal. Later he digested polysaccharides *in vitro,* using extracts of macerated intestine and pancreas in an 0.8% NaCl solution, but found no monosaccharides. He took this as evidence that there are no enzymes in the digestive system of mammals capable of splitting inulin, lichenin or hemicelluloses. On determining the action of fecal material and fermentative bacteria on these substances, Shimizer and Tonihide (13) concluded that they are split into sugars by the bacteria in the digestive tract of mammals and can then be absorbed.

It has been assumed in the past that the presence of the enzyme lichenase in the stomach contents of the ox and pig probably enables these animals to convert lichenin into the more digestible sugars. The action of snail lichenase on lichenin *in vitro* has been found to produce cellubiose and lichosan, an anhydride of glucose similar to cellosan, a product of cellulose. Messerle (13) states that the livers of snails contain much lichenase which converts cellulose to sugar. Jewell and Lewis (13) had found this to be true of many invertebrates, suggesting that the ability to hydrolyze lichenin may be characteristic of invertebrates only.

Swartz (13) questions the value of algae and lichens as sources of energy in nutrition. Oshima suggests that they may be valuable for their inorganic salts, while Prausnitz (13) calls them "faeces-forming foods" in that they stimulate intestinal activities. Most of Swartz's studies were on the algal components, yet she was able to draw certain conclusions concerning those chemical substances which are common to both components. They were:

a) Nutritive studies of lichens would indicate that as energy-producers their value is not appreciable. Yet the fact remains that certain animals do feed upon them and thus sustain themselves in regions where energy and high body heat are prerequisites of life. The assumption follows that our understanding of the value of lichens as fodder is still incomplete, though ruminants are apparently more effective users of hemicellulose than other animals.

b) Aerobic and anaerobic bacteria, not enzymes, are responsible for conversion of hemicelluloses into sugars. The amount available to the animal system is extremely diverse, depending on the animal and the lichen species.

Vitamin Studies. Blix and Rydin (13) found that *Cladonia rangiferina* contains some ergosterol, more than most lichens, but the content is low in comparison to that in yeasts and molds. This same species collected in Uppsala in August and September showed only traces of Vitamin D.

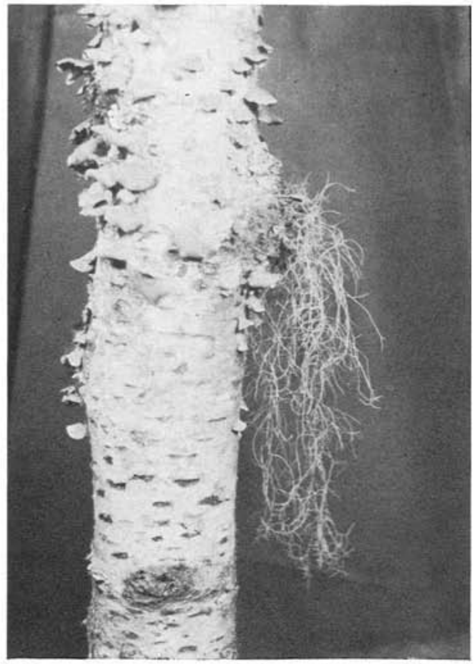
Feeding experiments with rats failed to show Vitamin B or G in either of two samples of short and tall lichens obtained in Alaska. Short-growth lichens gave more Vitamin A and less Vitamin D than tall-growth types. Short-growth types appeared more palatable to rats. Unfortunately the names of the lichens used were not indicated, so that this evidence is only of the most general interest. Bourne and Allen (13), using acetic acid-silver nitrate reagent for Vitamin C, obtained a positive test in lichens.

Medicines and Poisons Derived from Lichens

The name "lichen" (= Leprous), originally applied to hepatics, is of Greek origin and was used by Theophrastus in his "History of Plants" to describe a superficial growth on the bark of olive trees. Dioscorides applied it to true lichens because of their resemblance to the cutaneous disease for which they were supposed to be specific.

History. The use of lichens in medicine can be traced back to antiquity. *Evernia furfuracea* has been found in an Egyptian vase from the 18th Dynasty (1700–1600 B.C.), and is still imported into Egypt from Europe and sold with *Cetraria islandica* as a foreign drug. The Egyptians also used this species of *Evernia* to preserve the odor of spices employed in embalming mummies; it has been identified in one such body (500–800 B.C.) by Edward Tuckerman who noted the similarity of this species to that occurring in Maine.

In the 15th century A.D. there was throughout Europe a constant attempt to follow the guidance of nature in the study and treatment of disease. It was believed that Providence had scattered here and there on plants "signatures" of resemblances more or less vague to parts of the human body, or to diseases to which man is subject, thus indicating the appropriate specific. This era climaxed the commercial importance of these plants, for never before or since have they played such a unique role in the world of economic plants. The long filaments of *Usnea barbata* Web. were used to strengthen the hair, though Hippocrates also prescribed it for uterine ailments. The natives of the Malay Peninsula still use a closely related species for treating colds and strengthening after confinement (13). *Lobaria pulmonaria* Hoff. was the suitable remedy for lung troubles. Boerhaave (19) regarded it as an excitant, tonic and astringent, and recommended it for hemorrhages and asthma. *Xanthoria parietina* Th. Fr., being a yellow lichen, was supposed to cure jaundice, while *Peltigera aphthosa* Willd., the thallus of which is dotted with small wart-like tubercles, was recommended for children who suffered from "thrush". Other species of *Evernia, Peltigera, Parmelia, Cladonia, Roccella* and *Pertusaria* were used as purgatives or to control fevers, diarrhea, infections, skin diseases, epilepsy and convulsions. *Pertusaria communis* DC. was especially interesting in that it was used to cure intermittent fever, having less action on women than men. *Peltigera canina* Willd., as a cure for hydrophobia, was sold by a Dr. Mead as the celebrated "Pulvus antilyssus" (Dillenius, 1741). The so-called drug "Lichen quercinus virdes" consisted mostly of *Evernia pru-*



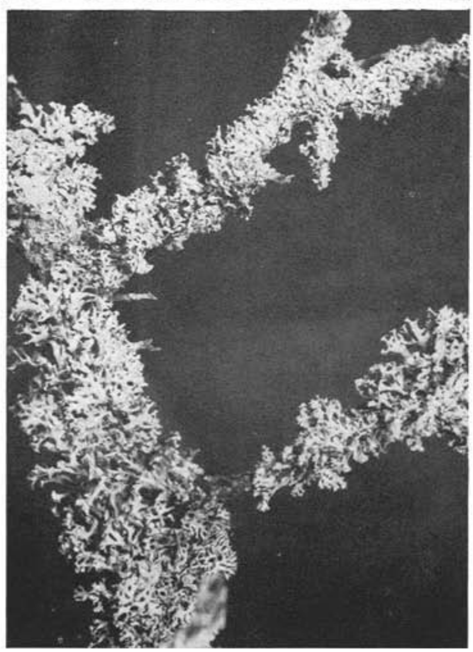


FIG. 6. (*Upper*). Beard lichen, *Usnea* sp., growing on birch, Mt. Desert Island, Maine, U.S.A.

FIG. 7 (*Lower*). *Parmelia physodes*, showing its dense growth on the branch of a pine tree. Mt. Desert Island, Maine, U.S.A.

nastri, E. furfuracea and *Parmelia physodes* Ach., (19). The doctrine reached the height of absurdity in the extravagant value set on a lichen found growing on human skulls, "Mucus cranii humani". This skull lichen (*Parmelia* or *Physcia?*) fetched its weight in gold as a cure for epilepsy.

Luyken, in his "Historia Lichenum in Genere", Göttingen, 1809, gives a long list of medicinal "Lichenes, quorum usus obsoletus est". Plitt (13) recommended more emphasis on the study of lichenology to pharmacognosists, venturing the opinion that the medical virtues of bark drugs may be affected by the lichens growing on them. Feé dealt earlier on this subject in a beautifully illustrated treatise (7).

"Iceland Moss" was given an important place in medicine by Linnaeus in 1737. It has been used in chronic affections as an emollient and tonic, and it would indeed have been a "Divine gift to man" had it lived up to all its prescriptions. Today it is employed as a substitute for salve bases, in the preparation of emulsions, the reduction of the bitter taste in certain drugs, as a laxative and as a culture medium in laboratory technique. With the exception of this lichen, all have been replaced by more effective modern drugs so far as medicinal use is concerned.

Physiology. The physiological action of the cetraric acid of "Iceland Moss" has been studied by Kobert (13). It has no poisonous effect either when injected into the blood or when taken into the stomach of small animals. Small doses induce peristaltic movements in the intestines. Large doses may injure an animal, but if given as free cetraric acid it passes through the stomach unchanged to become slowly and completely dissolved in the intestine. The mucous membrane of the intestine of animals that had been treated with an overdose was found to be richer in blood, so that Kobert assumed that cetraric acid would be useful in assisting digestion. There is also the possibility that the lichen acid inflamed the sensitive mucous membrane. By means of acetone, d-usninic, evernic and obtusatic acids have been extracted from *Ramalina calicaris* (13). The last named acid was the same as "Makao" obtained from the Manchurian drug, "Shi-hoa".

Lichens, with two exceptions, are non-poisonous, though some acid substances in others may be irritating when taken internally. The poisonous exceptions are *Evernia vulpina* and *Cetraria pinastri,* both a characteristic bright yellow. The former contains vulpinic acid in the cortical cells, the crystals of which are yellow in the mass. The latter species and *Cetraria juniperina* Ach. produce pinastrinic acid in the hyphae of the medulla, and the crystals are orange or golden-yellow. These lichens have been used in northern European countries to poison wolves by stuffing them and powdered glass into bait (18). Santesson isolated the crystalline acid and tested it on animals; it produced respiratory difficulties, reducing the rate of breathing until death ensued.

More recently a report of the Wyoming Agricultural Experiment Station on a study of the presence of selenium in soil and various plants states that *Parmelia molliuscula* Ach. contains this poisonous salt in sufficient quantities to affect sheep and cattle. It produces a lack of coordination of the hind limbs; in severe cases the animals are unable to move either hind or fore legs. Other examples of lichens containing such elements include beryllium in *Parmelia saxatilis* Ach. and *Xanthoria parietina* Th. Fr., chlorine in *Evernia furfuracea* (13).

Modern Developments in Lichenology. Employment of lichens as raw materials in pastries, confectionery, foods, and in the production of alcohol depends largely on the properties of "lichen starch". The presence of a certain number of phenols, acid-phenols and acid-phenol-ethers, together with other substances in the extracts of some lichens, forms the basis of their use in perfumery and cosmetics. The tinctorial properties of lichens are for the most part derivatives of orcinols, as in species of *Roccella*. Besides possessing lichenin and isolichenin and the sugar alcohols such as erythritol and manitol, lichens have as their most characteristic components the lichen acids which seem to be built on an altogether original pattern. In the past 50 years more than 200 of these lichen acid compounds have been isolated. These compounds are, for the most part, known only from the Class Lichenes and were originally thought to be peculiar to them alone. Raistrick (15) introduces new findings, however, remarking that the isolation of two lichen acids, parietin and physcion, from the lower fungi is an ". . . observation . . of some biological interest since . . . . (it) gives strong evidence for the view that the so called lichen acids owe their origin to the fungal half of the the fungus-alga symbiont.—The presence of chlorine containing metabolic products (of the Lower Fungi) emphasizes the close metabolic relationship between moulds and lichens, since two of the very few organic chlorine-containing substances occurring in nature have been isolated from lichens, *i.e.*, gangaleoidin and diploicin". Research on lichen acids began with the Germans —Zopf, Hesse, Fischer and others—but

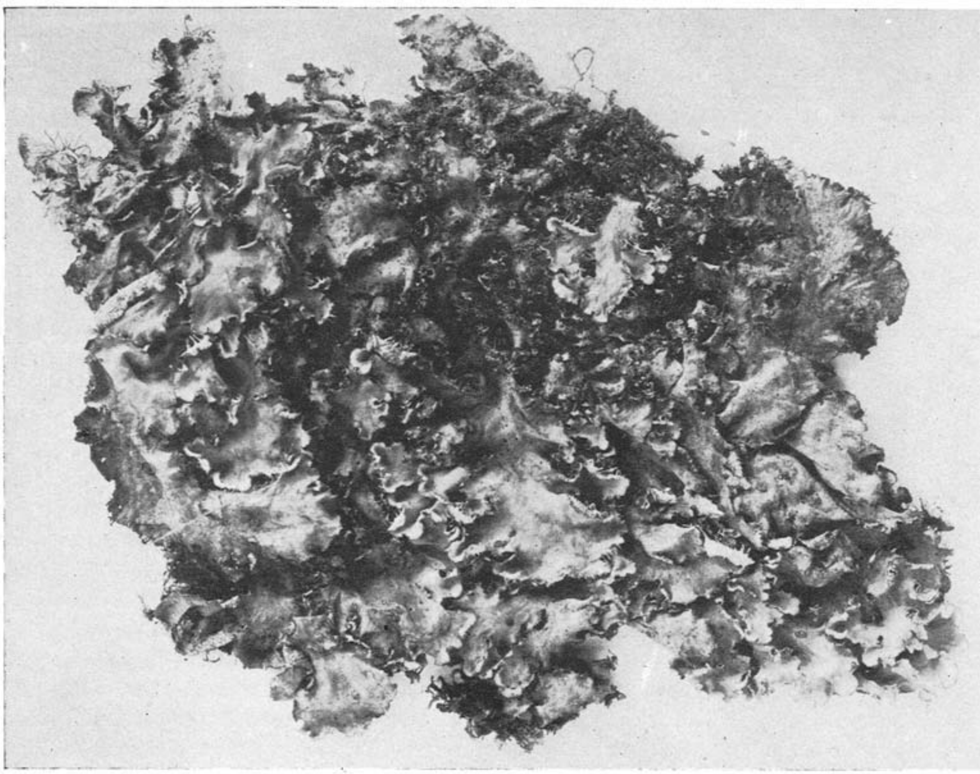


FIG. 8. Dog lichen, *Peltigera canina,* preparations of which were regarded in the Middle Ages as efficacious in treating rabies. (*Courtesy The New York Botanical Garden*).

received most attention from the work and simplified methods of extraction of Asahina and his Japanese colleagues. These studies are being continued today by Sao, Sastry and Seshadri of Andhra University, Waltair, India, and by the workers at University College, Dublin, Ireland—Breaden, Davidson, Hardiman, Jones, Keane, Murphy and Nolan—who are contributing detailed information on the chemical constituents of the lichens in their respective areas. The research of these workers is basic to the recent experimental aspects of lichenology. In view of present day résearch, this information has passed from the sphere of academic interest and begins to assume real value in practical application as well as to present a more complete understanding of the biology of this group of plants.

Since the discovery of the chemotherapeutic effects of penicillin, the phenomenon of antibiosis has attracted widespread attention and stimulated the investigation of other plant groups. Some investigators (2), studying the antibiotic activity of lichens, proceeded with their studies on the basis that since the "antibacterial activity of the green alga *Chlorella* and the many antagonistic substances known to be produced by numerous kinds of fungi, the lichens seemed to offer favorable material for antibiotic investigations inasmuch as lichens . . . consist of algae and fungi". Using the cylinder plate procedure, they analyzed the antibacterial activity of extracts from 42 species of lichens, later extending the work to 100, of which 27 species were found to be active against *Staphylococcus aureus* and *Bacillus subtilis,* while four species inhibited the growth of *Proteus vulgaris* and *Alcaligenes fecalis;* none of the lichen extracts used in the test showed antagonism against *Escherichia coli.* That more than one antibiotic compound may exist in lichens is suggested by the fact that both *S. aureus* and *B. subtilis* are inhibited by extracts from *Cladonia Grayi, Parmelia physodes* and other lichens, while substances obtained from some species of *Cladonia* inhibited *B. subtilis* but not *S. aureus.* Extracts from *Cladonia furcata* Schrad., *Cl. papillaria* Hoff. and *Umbilicaria papulosa* inhibited *S. aureus* but were inactive against *B. subtilis.* Furthermore, the inhibition of some Gram-negative bacteria by selected species of lichens lends further support to the theory of multiple substances. The authors pose the question:—Do the characteristic lichen acids possess antibacterial activity or are the antibiotic properties of lichens related to traces of other unidentified substances synthesized by these plants? Burkholder and his associates noted that some of the lichen compounds possess certain structural features in common with antibacterial substances isolated from molds, but they could not be sure that these were responsible for the antibiotic phenomena observed. They point out the fact that "almost nothing is known about the anabolism of the components or the roles of the various substances formed in the lichen body". In a subsequent report, Burkholder and Evans (3) reach the conclusion that "the phenomenon of antibiosis . . . is well exemplified in the lichens". These antibiotic substances are apparently different from penicillin, for the activity of several species of lichens was not lost after boiling in Na_2CO_3 solution. Samples of lichens collected from different regions showed, on the whole, characteristic activity in antibiotic tests with suitable bacteria. No explanation is offered for the variability, though there may be some relationship between this phenomenon and the fact that some of the diagnostic lichen acids vary in different samples of some lichen species. Though diagnostic compounds known to occur in the antibiotic species of *Cladonia* are listed, the authors suggest that other unidentified substances might be responsible for the observed antibacterial properties. The presence of antibacterial substances in numerous species of *Cladonia* and in representatives of other genera of lichens appears to be definite, but whether these are bacteriocidal or merely bacteriostatic is not proven. Although Gram-positive bacteria, including several pathogenic types, are inhibited, Gram-negative bacteria, with a few exceptions, are generally not susceptible to the antibiotic substances of lichens.

Other research (1*a*) on anti-tubercular compounds indicates another promising possibility for a lichen compound. Numerous acids were the subject of synthetical studies by various workers in the field of anti-tubercular compounds. Barry began with roccellic acid isolated from *Lecanora sordida* Th. Fr. The author states: "We have already reported that this substance in the form of its half-esters or half-amides inhibits completely the growth of the tubercle bacillus *in vitro* at a dilution of about 1/500,000". Barry adds that "the most active of these compounds are at the moment being tested in animal protection experiments, and although they are strongly antagonized by serum *in vitro*, they seem to have some activity in the animal".

Industrial Uses of Lichens

Brewing and Distilling. Use of lichens instead of hops for the brewing of beer has been mentioned as having occurred in one or more monasteries of Russia and Siberia which had a reputation of serving bitter but highly intoxicating beer to the traveller. Tuckerman further describes a by-product of *Lobaria pulmonaria* Hoff. when it was used as "a yellow, nearly insipid mucilage which may be eaten with salt".

Alcohol production from lichens is an old art, now replaced by increased cultivation of potatoes, importation of sugar and distillation of wood. Preparation of spirits from lichens was recommended in 1870 as a means of saving grain otherwise diverted into alcohol production. It was claimed that 20 pounds of lichen would yield five liters of 50% alcohol. Stenberg (20) published a report in Stockholm in 1868 on the production of lichen brandy, and included detailed plans for setting up a distillery with figures of possible production levels. By 1893 the manufacture of brandy from alcohol derived from lichens had become a large industry in Sweden, but by 1894, as a result of the local exhaustion of the plants, the industry languished. Arendt (13) in 1872 reported that this originally Swedish discovery was being applied in the Russian Provinces of Archangel, Pskow Novgorod, *etc.*, and that various distillers exhibited samples of lichen spirits at the Russian Industrial Exhibition in Moscow, which were highly approved by the French and English visitors. The industry was a lucrative one in the northern provinces of Russia, yielding a net revenue of from 40 to 100%. Others (6) have reported on the carbohydrate composition of lichens on the Kola Peninsula, considered in connection with the problem of glucose production in northern localities. This includes a tabulation of carbohydrates present in eight lichen species, which shows them to be rich in polyhexoses, but poor in cellulose and in pentosan. Two small factories in Kirovsk have demonstrated the possibility of subjecting lichens to preliminary treatment with weak alkali solution in order to convert the bitter tasting lichen acids into soluble form. This is then hydrolyzed with dilute H_2SO_4, neutralized with chalk and purified with activated charcoal to produce a molasses containing 65 to 70% glucose. From this, crystallized (lump) glucose was obtained. The yield of molasses was 100%, based on dry lichen weight. However, molasses produced by this process from lichens of the Cladonia group, especially *alpestris*, has a bitter taste, "the cause of which the authors are investigating".

Lichens vary in the amount of carbohydrates (lichenin) present. *Cetraria islandica* and *Cladonia rangiferina* have been found to yield up to 66% of polysaccharides which are readily hydrolized to glucose and then almost completely fermented to alcohol. Besides sugars capable of fermentation, lichen acids up to 11% of air-dried substance may be present. These acids as well as sodium chloride have been found to retard the process. Experiments with *Cladonia rangiferina* have shown a total yield of 54.5% sugar which on fermentation produced 176–282 cc. of alcohol per kilo. Maximum returns of alcohol were obtained by steaming the lichens one hour under three atmospheres pressure, adding 2.5% of 25% HCl, resteaming for the same period of time and pressure, and finally neutralizing the product. Subsequent growth of yeast was normal, though fermentation could be accelerated by addition of H_3PO_4. An interesting modification of this procedure through addition of three parts by weight of H_2SO_4 and one part by weight of NCl at room temperature gave a pentanitrate similar to cellulose nitrate which, on gelatinizing with a solvent, produced a substance resembling horn (13).

FIG. 9. *Parmelia saxatalis* on the lower side and *P. centrifuga* on the upper side of a rock. (*Photo by Auer, Finland*).

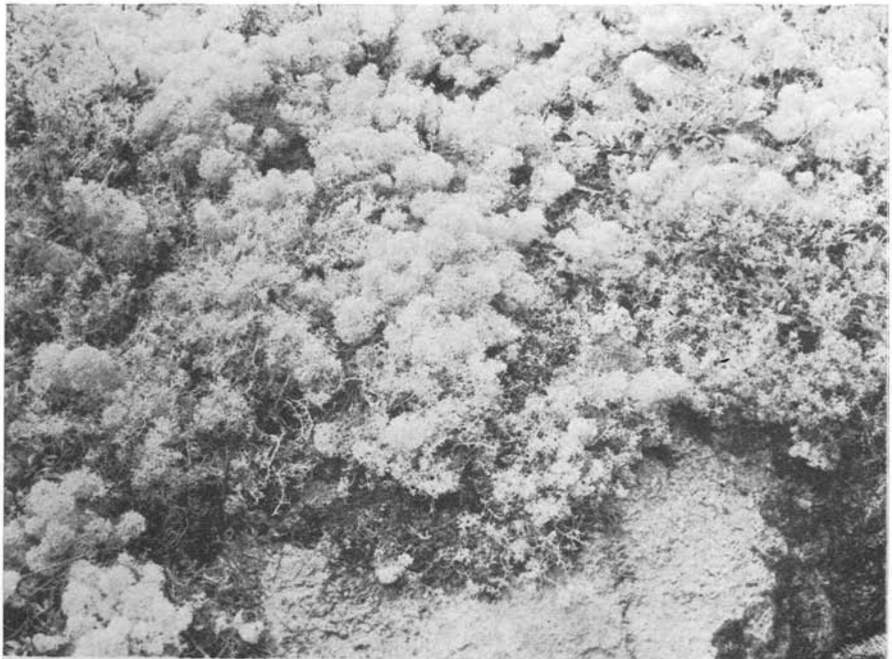
Tanning. The tanning quality of lichens is due to an astringent property (depsides) peculiar to some species. *Cetraria islandica* and *Lobaria pulmonaria* were most used, and though not occurring in quantities sufficiently large to warrant industrial application, have been locally employed on a small scale.

Dyeing. Synthetic dyes have largely replaced many formerly common vegetable dyes in the textile industry, primarily because of their low production cost and the fact that they generally surpass the natural products in fastness, particularly light fastness. Of the vegetable dyes, those obtained from lichens were renowned among the peasant dyers of old for their high quality and color, but today are the least known. Some of them are still popular in rural districts of Great Britain and the Western Islands, Iceland, Scandinavia, France and Germany. Interest in lichen dyes is being revived today somewhat in Scandinavia because of their use by the Hemslöjd (Home Industries Association), while there is some indication that the Irish Government is trying to reestablish this art in the poorer farming and fishing districts where these skills have been lost. That there is a good economic reason for such revival may be noted by the fact that the production of Harris Tweed cloth, dependent upon lichen dyes, is a carefully organized industry in Great Britain producing a luxury cloth of standard quality and great demand. The most attractive feature of home dyed and woven cloth is not only the dye utilized in its manufacture but also the individuality of the patterns evolved by a particular household or community. When these are standardized, as they may be through government and association intervention, they lose much of their appeal to the retail trade. Under such controls prices tend to rise in excess of the true value, even for handicraft. It has been observed that wool dyed with lichen dyes is not attacked by cloth moths.

Mairet (13) states that none of the great French dyers used lichen dyes, nor are they mentioned in any of the old books on dyeing. Yet Amoreux, Hoffmann, and Willemet (13) published simultaneously in 1787, giving directions and samples with color names of lichen dyes as used by the French "tinctures" of their day, reflecting in part the universal application of these plants. Westring's (22) treatises on this subject, published from 1791 to 1806 in Sweden, are collectors' items, containing hand colored plates of the lichens and small water color panels illustrating the colors obtainable. These works established their author as an authority, and he is the source of information in later numerous, and often unacknowledged studies. Westring's system of the classification of lichen dyes distinguishes between lichen dyes which impart color to pure water (essential pigments) and those requiring certain treatment to yield color (preparable pigments). Lebail (13) in 1853 and Lindsay (11) in 1854, as well as others, classified lichen dyes according to the color produced, recognizing, however, that color varied with treatment.

History. Of all the lichen dyes used by man, none has attained greater historical and commercial importance than those of the Roccellaceae, variously known to the English as Orchella Moss, Orchella Weed, Orchil Paste or Orchil Liquor, to the French as Orseille, and to the Germans as Persis. Orchil and cudbear are preparations of lichens and not the actual plants. Lindsay (12) states that: "We may practically regard Orchil as the English, Cudbear as the Scottish, and Litmus as the Dutch name for one and the same (?) substance. The first being manufactured in the form of liquid of a beautiful reddish or purple colour; the second in the form of a powder of a lake or red colour; and the third in that of small parallelopipeds or cakes of a blue color. The commercial or trade designations of the dye-lichens depends upon the thallus being erect or pendulous, cylindrical or shrubby or flat, crustaceous, foliaceous, and closely adhering to the substrate. The former are "weeds" (*Roccella*); the latter are "mosses" (*Lecanora* and *Parmelia*)". The attempt to combine trade names and utilitarian characteristics with imperfectly known taxonomic features produced these peculiar groupings of widely different species.

Theophrastus and Pliny appeared to have been familiar with the dye of the Roccellaceae, while a Biblical reference has their origin in the "Isles of Elisha". During the Middle Ages the art of making this dye fell into disuse, and it disappeared from the markets of the world until the 17th and 18th Centuries when it again took on the aspects of an industry, and the "Weed" became an article of international exchange comparable to spices. Lindsay was particularly interested in the commercial aspects of lichens. His recommendations for a fuller investigation of the subject throws some light on the economic aspects of lichens in trade. He indicates that the field is comparatively new, and open to many possibilities, especially if the lichen resources of Scotland were exploited. "The speculation (investment?) of substituting home for foreign dye lichens promises to be remunerative as the roccellas have frequently reached the high price of £1,000 per ton in the London market". In 1855 he reemphasized that "if commanders of ships were aware of the value of these plants, which cover many



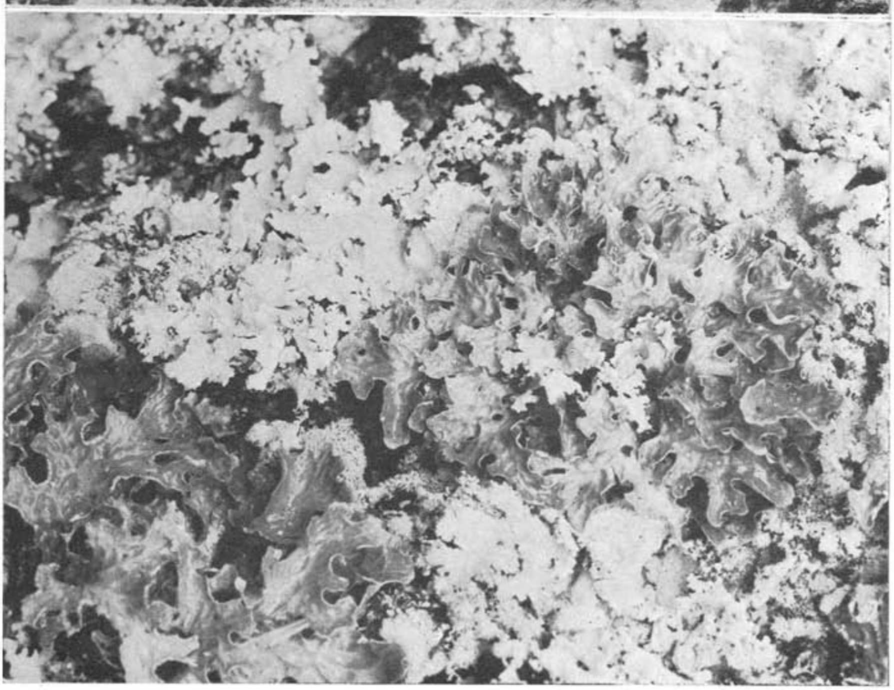


FIG. 10 (*Upper*). *Cladonia alpestris* (in clumps) and *Cl. rangiferina* (not in clumps) on Mt. Desert Island, Maine, U.S.A.

FIG. 11 (*Lower*). *Lobaria pulmonaria* growing with lighter colored forms of Parmeliaceae on a tree trunk. Mt. Desert Island, Maine, U.S.A.

a rocky coast and barren island, they might with a slight expenditure of time and labour bring home with them such a quantity of these insignificant plants as would realize considerable sums, to the direct advantage of themselves and the shipowners; and consequently to the advantage of the State''. He even compromised the reforms of social revolution with the possibility of financial returns, saying that ''indirectly, a multiplied trade in dye-lichens might scatter the seeds of civilization, and place the means of a comfortable subsistence at the command of the miserable inhabitants of many a barren island or coast, at present far removed from the great centres of social advancement . . .''.

Blue and Red Dyes. About 1300 A.D. a Florentine merchant named Federigo (13) noted, while traveling in the Levant, that urine imparted a very fine color to some plants. On returning home he experimented, with success, and established the lucrative dye industry which founded the family name, Orcellarii, Ruccellarii or Rucellae, and gave to his native city a monopoly that persisted until the discovery of the Cape Verde Islands. This, though some think it derived from the Spanish term ''Orcigilia'', is thought to be the origin of the botanical term, Roccellaceae, which is descriptive of the group of lichens furnishing blue and red dyes. The first source of supply in the Levant and Mediterranean countries was controlled by the Rucellae and other merchants of Florence. Discovery of new lands broke this monopoly and revealed the abundance of the plants on rocks along warm sea coasts. The trading centers became, successively, Portugal, France and Holland. De Avellar Brotero (5) of Lisboa wrote in 1824, referring to the dye, that ''its uses have been much extended for it serves as pigment to dye wool, silk, cotton, and various other fibers, it serves in paints, to color marble, wines, liqueurs, papers, pills, oil, grease, wax, *etc.*''. New sources for the ''weed'' were found in the Cape Verde Island, Cape of Good Hope, Angola, East Africa, Mozambique, Madagascar, Zanzibar, Ceylon, the East Indies, Australia, Valparaiso (Chile), Lima (Peru) and the West Coast of North America. Shiploads of it were gathered from Lower California and adjacent islands.

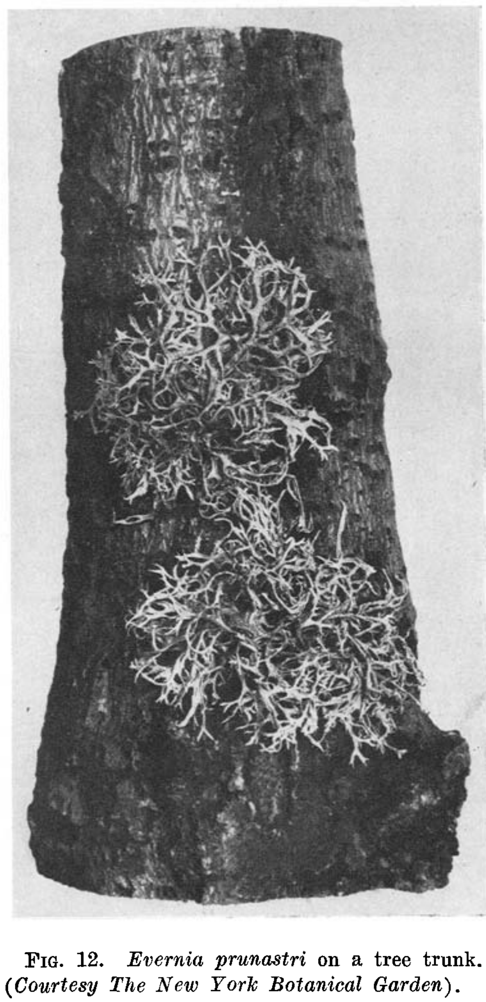


FIG. 12. *Evernia prunastri* on a tree trunk. (*Courtesy The New York Botanical Garden*).

The species which constitute the commercially valuable orseille lichens have been grouped as follows into orseilles of the earth (A) and orseilles of the sea (B), with the most important marked by an asterisk (16):

DYE LICHENS AND THEIR SOURCES

Locality	Type	Species
Pyrénées, Alps, Cévennes (France)	(A)	*Pertusaria dealbata* Cromb.
Auvergne (France)	(A)	*Lecanora parella* Ach.
Sweden	(A)	*Lecanora tartarea* (L.) Ach.
Norway	(A)	*Umbilicaria pustulata* (L.) Hoffm. and other *Umbilicaria* sp.
Canary Islands (Atlantic Ocean)	(B)	*Roccella tinctoria* Lam. & DC.
Madeira (Atlantic Ocean)	(B)	*Roccella tinctoria* Lam. & DC.
Mogador (North Africa?)	(B)	*Roccella tinctoria* Lam. & DC., *Ramalina scopulorum* Ach. and others.
Manila (Gorée) (Philippine Islands)	(B)	*Roccella portentosa* Mont.
Sardinia (Mediterranean)	(B)	*Roccella phycopsis* Ach., *Roccella tinctoria* Lam. & DC.
Angola (Africa)	(B)	*Roccella Montagnei* Bél.
Valparaiso (South America)	(B)	*Roccella portentosa* Mont.
Ténérife (Canary Islands)	(B)	*Roccella tinctoria* Lam. & DC.
Mozambique (East Africa)	*(B)	*Roccella Montagnei* Bél.
Madagascar (Indian Ocean)	*(B)	*Roccella Montagnei* Bél.
California (North America)	*(B)	*Dendrographa leucophaea* (Tuck.) Darb.
Cape Verde Islands (Atlantic Ocean)	*(B)	*Roccella tinctoria* Lam. & DC.

Importers of old were always reluctant to disclose the origin of their best supplies, but *R. tinctoria* of the Cape and South America were "6–8 inches long and as thick as goosequills" and so regarded highly by the dye merchants (40). In 1750 the Cape Verde and Canary Islands exported 100 tons annually to England. By 1818 the cost had jumped from 40 to £200 per ton, depending on the quality, but in 1886, with a stable supply from Ceylon where *R. tinctoria* grows abundantly on palms, the price settled at £50 per ton. Specimens of *R. fuciformis* DC. were exhibited at the London Crystal Palace in 1851, at which time the price quoted was £380 per ton. The latest figures available list the importation of tanning and dyestuffs into England for 1935 (13) as annatto, 837,919 pounds; Brazilwood, 854,581 pounds; lichen dyestuffs, 411,265 pounds.

The chemical nature of Roccella dye was not understood in early days, a lack of information that was further complicated by trade secrets and tradition. In the old English method the lichen was cut small or reduced to a powder by passing it through a sieve, and placed in iron drums provided with paddles. The mass was moistened slightly with stale urine, the mixture being stirred once a day with additions of soda for five or six days at a temperature of 35° to 45° C. Fermentation proceeded and was checked frequently until the coloring matter, a dove grey, ceased to increase. The product, Orchil Paste, was then placed in wooden casks and covered with lime water or gypsum solution until needed by the dyer. To make Orchil Liquor the lichen was treated with water and urine and permitted to ferment as for Orchil Paste, after which the fibrous matter was removed and the liquor collected and stored. Sal ammoniac and saltpetre were sometimes used in the process. Dillenius, 1741, "reckoned (the color) more beautiful when first dyed, than the Tyrian Blue", while Bancroft (13), in 1832, described the infusion of Orchil as of a red crimson inclining to violet.

Modern methods are based on more accurate knowledge of the chemistry of the lichen dye. According to Hill (13), the lichen is sprayed with ammonia until the mass turns color, when the blue Orchil Liquor is extracted with water; if heated until the ammonia is driven off, red orchil results; afterwards the plants are dried and ground to a fine powder.

The French employed a crustaceous species commonly called "perelle" to obtain a purple-blue dye. M. Cocq, in the 81st volume of the Annales de Chimie, describes its preparation as observed at Clermont, France. The lichen was macerated in wooden troughs, six by three by two feet, and fitted with tight covers. Two hundred pounds of perelle and 240 pounds of urine were mixed in the trough and stirred every three hours for two successive days and nights, care being taken to keep the covers closed to avoid loss of the volatile alkali (ammonia). On the third day, ten pounds of sifted, slaked lime were added and well mixed with a quarter-pound of arsenic and an equal weight of alum. The mass was then stirred several times, once every quarter-hour, later every half-hour until fermentation was established, to prevent the formation of a crust on the surface of the mass. Fermentation was renewed by adding two pounds of sifted lime, and stirring once every hour for five days. On the eighth day it was stirred every six hours, and the processing might extend a fortnight to three weeks. The coloring matter was kept moist in closed casks until used. It was said to improve the first year, to suffer little change during the second year, and to begin to deteriorate in quality during the third year of storage.

Bancroft recommended the use of ammonia instead of urine, and of hogsheads to facilitate agitation; the addition of arsenic and alum he considered useless and dangerous. Use of human urine was commonplace, since it was the only early source of ammonia, and Lindsay (12) states that manufacturers recognized different qualities of it in producing the coloring matter: "Hence, I have been informed that some English manufacturers who continue to use this form of ammiacal solution, have learned by experience to avoid urine from beer-drinkers, which is excessive in quantity but frequently deficient in urea and solids, while it is abundant in water".

Brown and Yellow Dyes. Employment of brown and yellow dyes is an old custom in the northern countries of Europe. Fries remarked on the use of the class Lichenes, in the Arts "that almost all that is known has been owing to the Northern—the Anglo-Saxon, Scandinavian and German—Nations whom necessity constrained to value all of Nature's gifts". In certain districts of Scotland, as Aberdeenshire, almost every farm or cotter had its tank or barrel ("litpig") of putrid urine ("graith") wherein the mistress of the household macerated some lichens ("crotals" or "crottles") to prepare dyes for homespun stockings, nightcaps or other garments. The usual practice was to boil the lichen and woolen cloth together in water or in the urine-treated lichen mass until the desired color, usually brown, was obtained. This took several hours, or less on the addition of acetic acid, producing fast dyes without the benefit of a mordant or fixing agent. The color was intensified by adding salt or saltpetre. This method was prevalent in Iceland as well as in Scotland for those homespuns best known to the trade as "Harris Tweed".

Campbell, in the National Geographic Magazine, February, 1947, states that in the Hebrides "lichens from the rocks supplies a dye of misty brown, but the fishermen do not use this color while in their boats believing that what is taken from the rocks will return to the rocks". Horwood (13) reported that in the Shetlands the lichens were harvested in May or June or after rain in the autumn or winter, a metal scraper for rock species

FIG. 13 (*Upper*). Hemslöjd group near Uppsala, Sweden, with paraphernalia for dyeing with lichens collected in the immediate vicinity. The equipment consists of iron and copper pots heated over wood fires, chemicals and accessory dyes, and a small scale.

FIG. 14 (*Center*). Rinsing procedure, utilizing clean water of a stream. The white yarn is undyed and has been washed; the dark yarn has been dyed.

FIG. 15 (*Lower*). Drying the yarn after dyeing and washing (foreground). Undyed yarn hung up for convenience in handling (background).

being used. They were washed, dried in the sun and sometimes powdered, and were processed and shipped in casks to the London market as Cudbear. This term is derived from a corrupt pronunciation of the name of Dr. Cuthbert Gordon, chemist of Glasgow, who obtained a patent for his process of preparing the dye from *Ochrolechia tartarea* on a large scale. One person could collect 20 to 30 pounds daily, any one locality being visited every five years. After washing and drying, the collected weight was reduced to half.

Hooker (12) records that in 1807 at Fort Augustus a person could gain 14 shillings per week by collecting Cudbear, estimating a market price at three shillings, four pence per stone weight (22 pounds). Other observers have recorded it as an article of commerce about Taymouth, in Perthshire, in North Wales, Derbyshire, Westmoreland and Cumberland at one shilling one penny per pound in 1854, while the manufacturers of woolens and silks paid ten shillings a hundredweight for it with a profit of eight pence to the middleman. The manufacture of Curbear flourished about Leith and Glasgow because *Ochrolechia (Lecanora) tararea* from which it was prepared first came from the Western Highlands and islands around Scotland and was a chief source of revenue to the "poor Highlanders" whose other source of income, gathering sea-weed for potash salts, ceased. The value of this lichen to Scotland was said to have averaged £10 per ton, though other species, as *Parmelia perlata* Ach., sold at from £190 to £225 per ton in 1851. The manufacture of Cudbear moved into the hands of English Orchil makers who imported their materials from Norway and Sweden for the London market. From 1785 to 1788 24,000 kilo were shipped from Flekherjord, Norway (9).

For home use (see appendix) the cotters would mix the crotals treated with graith into a coarse paste rolled into small balls or cakes with lime or burnt shells. These were wrapped in dock leaves and hung up to dry over peat fires, which accounts for the peat-smoke odor peculiar to homespun Harris Tweed cloth. In this fashion the dye would keep for a year or more; when needed, it was redissolved in warm water.

The colors of Cudbear and of Orchil are so similar as to be commercially indistinguishable. They dye best in a neutral bath producing a bluish-red or dull magenta shade but are frequently applied with sulfuric acid in conjunction with other vegetable dyes and coal tar dyes especially magenta. Addition of indigo and the dye of lungwort give a permanent black dye. *Roccella tinctoria* was used as the first dye for blue British broadcloth, having a purple tint against light. A variety of colors and shades can be obtained by the use of different species of lichens, varying the treatment with oil of vitriol, logwood or chemicals. Thus acids produce yellows, alkalies produce blues, lead acetate gives a crimson precipitate, calcium chloride a red precipitate, stannous chloride a red then yellow, while alum is more generally used by country folk for reds. The color of Cudbear is said to possess great beauty and lustre at first, but quickly fades and should never be employed unless for the purpose of giving body and lustre to blue dyes, as indigo ("bottoming"), or as a ground for madder reds (12). In deep shades the color has an intensity and body which cannot be equalled by coal-tar substances, and though they are not fast to light, milling or scouring, they do resist soaping but become bluer. Silks, and occasionally linens, have the dye applied in a soap solution with or without acetic acid.

Cudbear and Orchil have both been used in Holland for the manufacture of litmus, known to the French as "tournesol". After the dye is prepared, gypsum or powdered chalk is added and then cast into small, purplish-blue cubes, once sold as "lacunus". This, dissolved in water and soaked up in unsized paper, was retailed as litmus paper. This early product was rather unstable and tended to become colorless. The action is thought to be due to micro-organisms, so that alcohol or chloroform was often added when the litmus was stored in liquid form. Tincture of Cudbear was still used in the drug trade up to 1942 when the Dutch source of supply was no longer available and the U.S. Pharmacopeia recommended a coal-tar derivative, amaranth.

The chemical properties of dye lichens are better understood today because of the studies of the workers, previously listed. A comprehensive survey of lichen compounds may be found in Thorpe's Dictionary of Applied Chemistry, 4th ed., Vol. VII: 284.

Cosmetics and Perfumes

History. Since the 16th Century, or earlier, members of the families Cladoniaceae, Stictaceae, Parmeliaceae and Usneaceae have been utilized as raw materials in the perfume and cosmetic industries. At first this use consisted of drying and grinding the plants to a powder and combining them crudely with other substances, but as the manufacturers became more expert in their trade, these materials were skillfully combined into toilet powders, scented sachets and perfumes of real value. Three lichens commonly used were *Evernia prunastri, E. furfuracea* and *Lobaria pulmonaria* which have similar aromatic substances. The trades recognized these lichens under a variety of names, as "Lichen quercinus viridis", "Muscus arboreus, acaciae et odorante", "Eichenmoos" and more commonly as "Mousse de Chêne" or Oak-moss and Scented-moss. *Ramalina calcaris* Fr. was used in place of starch to whiten hair of wigs and perukes. Cyprus Powder, a combination of *E. prunastri, Anaptychia ciliaris* and *Usnea* species, was scented with ambergris or musk, and oil of roses, jasmine or orange blossoms for use as a toilet powder in the 17th Century that would whiten, scent and cleanse the hair (19). After a somewhat lengthy eclipse, these plants reappeared as raw stuffs for perfumery, owing to the creation of scènts with a deep tone and to the demands for the very stable perfumes of modern extraction, to which purposes they are almost universally applied to this day.

The principal species used in modern perfumes and cosmetics include *Evernia prunastri, E. furfuracea, E. mesomorpha, Ramalina fraxinea* Ach., *R. farinacea, R. pollinaria* Ach. and perhaps other species of the Ramalinae, though the last-named genus is not rated as so valuable as the former. *Lobaria pulmonaria* (Mousse de la base du Chêne) is used to some extent and is considered a more costly substance, perhaps because of its relative scarcity. Oak-moss (*E. prunastri*) of Europe is collected in shaded, damp habitats occurring in the central mountain ranges of Europe, the Piedmont of Italy and the forests of Czecho-Slovakia and Herzegovina. Not only the locality but the substratum is given a great deal of attention by the perfumer who differentiates between those plants that grow on oak (greenish) and those found on conifers (greyish); in the latter case rightly so, since resins may be included with the lichen, rendering it less desirable for the trade. In all instances the crop is gathered by peasants or shepherds, as in Jugoslavia, and pressed into large bales for export. The American supply before the war was derived from Jugoslavia, amounting to a few tons yearly at a cost of from five to seven and one-half cents per pound f.o.b., New York City. During the war a few companies, formerly established in France and Holland, became interested in developing the American market, but the lack of apt collectors willing to work for wages per pound equivalent to or slightly higher than those of the European gleaner rendered the commercial possibilities for the use of American plants somewhat doubtful. Experiments, including a number of North American species, have been carried out with little success, except with those traditionally used in the Old World. Of these there are sufficient quantities available in the northern forests of the United States and Canada to supply the domestic trade.

Chemical Properties of Essential Oil of Lichens. The use of dried, pulverized Oak-moss in the perfume industry is restricted, the principal sale being of extracts, essences and resinoids. Gildermeister and Hoffmann (13) state that the method of treatment involves exhausting the lichen by means of volatile substances and then removing the resins, waxes and chlorophyl with acetone. Addition of alcohol gives an "extract of Oak-moss" which may be used in this form or may be further concentrated in order to obtain a semi-fluid substance. French and German industrial research during the last 30 years has revealed much of the chemical nature of the extracts, gums and mucilages produced when processing lichens. Gattefossé (13) made a study of the essential oils and alcoholic extracts of all those lichens which were utilized as Oak-moss, obtaining data that caused him to conclude that oil of Oak-moss was almost exclusively a compound of phenol called "lichenol", an isomeric compound of carvacrol. These results were verified by St. Pfau (13) who further expressed the opinion that sparrassol, a metabolic product of the fungus *Sparassis ramosa*, is identical with methyl everninate resulting from the alcoholysis of everninic acid, present in proportions of about 2.8%, with a characteristic anise seed odor. Walbaum and Rosenthal (13) repeated the experiments of Gattefossé and arrived at different results. They distilled the oil of *Evernia prunastri* and found that at ordinary temperature it formed an oily crystalline mass of dark color with a very powerful and agreeable odor. Further analysis revealed Gattefossé's error, and orcinol monomethylether, not lichenol ($C_{10}H_{14}O$), is the principal constituent of Oak-moss. This phenol, though not the main odoriferous part of the lichen oil, has a pleasant, creosol-like smell, and an ester, β-orcinol methyl carboxylate ($C_{10}H_{12}O_4$) which does not enter into the odor of the Oak-moss oil. In the resinous precipitate Walbaum and Rosenthal found ethyl everninate generated only during the extraction through esterification of the everninic acid ($C_{17}H_{16}O_7$) which was found to occur in a free state in the lichen; when boiled with baryta water it split into orcinol and everninic acid with the liberation of carbon dioxide. This acid is closely related to β-orcinol monomethylether and would be converted into it by the liberation of carbon dioxide. For these reasons Walbaum and Rosenthal felt that the genesis of the principal constituent of the odoriferous substances of Oak-moss had a close connection with the origin of everninic and evernic acids. Stoll and Schener (13) found in the volatile fraction some compounds which may also have a function in producing this odor, mainly thujone, naphthalene, borneol, camphor, civeole, citronellol, guaniol, vanillin, methylnonylketone and stearic aldehyde.

The multiplicity of types of essences and extracts may be due in part to the diversity of substrata on which these lichens grow as well as to the varying mixtures of species offered to the manufacturer in any lot, and the mode of extraction. This is also verified by the theory of multiple substances in lichens, as proposed by Burkholder and Evans (3). Hess (13) was able to extract atranorine and everninic acid from a specimen of *Evernia prunastri* growing on oak, but not from samples collected on beech or birch, while a sample from a lime-tree yielded some usnic acid. The whole problem is further complicated by the fact that most constituents of Oak-moss react upon the solvent. Treatment of lichen extracts with alcohol is seldom employed for preparation of essences, since it alters the evernic acid. Thus the lichenol obtained by Gattefossé, using this method was everninate of ethyl. The synthesis of everninic, divarine and other acids has been performed in the laboratory but has not been applied on a commercial scale. In the trade the oil is extracted by means of low boiling solvents, after which it is purified and decolorized, the process yielding 0.2 to 0.3 kilo of the raw extract or 20 to 30 gr. of the pure essential oil, depending on the technique of extraction in which 100 gr. of the dried lichen yield 8.5 gr. of crude everninic acid.

Uses of Essential Oils. The essential oil of Oak-moss or "concrete" is used in its natural condition in soap as an impalpable powder or in the form of a resinarome. The powder permits production of soap-balls agreeably scented at a reasonable price if the manufacturer can obtain a perfectly impalpable powder; otherwise they give the impression of containing sand. The soap manufacturer maintains the quality of his product by procuring his raw material from a reliable purveyor. To be sufficiently scented, soap balls should have 1 or 1½% by weight of lichen powder. When used for this purpose Oak-moss "concrete" improves, strengthens and cheapens lavender-scented products. It is essential in the higher grades of cosmetics in combination with other aromatic oils, *e.g.*, jasmine, tuberose and orange blossom. Iceland Moss, *Cetraria islandica*, has already been mentioned in connection with foods and medicine; in the field of cosmetics it serves as a source of glycerol in the soap industry and in the manufacture of cold creams because of its lack of odor. Some lichens, *e.g., Sticta fuliginosa* Ach. and *S. sylvatica* Ach., have an objectionable fishy or methylamine smell.

The parfumeur recognizes abstract qualities in lichens which enhance his product. The peculiar reciprocity of the components forming the lichen unit and known to the unromantic biologist as "symbionts", are but an example of harmonious blending appreciated by the parfumeur. Therefore the extract of Oak-moss or Scented-moss "agrees" and "harmonizes" in the "happiest manner" with a large number of other essences. Its fragrance has been likened to musk-lavender, and as such it may be used as a fixative of the poppy type, blending well with bergamot, citron, acetate of lynalyl and linalol, thus supplying freshness; with neroli, jasmine, rose and cassia it improves the flavor of these flowers; it gives flexibility to tarragon, coriander, portugal, ylang-ylang and vanillin; contributes stability and depth to patchouli, vetyver, coumarin and musk, and "elevation" to alpha ionene. It also blends well with synthetic oils, *e.g.,* amyl and isobutyl salicylate and aceto-phenone. It is considered as an indispensable basis of numerous perfumes known to the trade as Chypre, Fern and Heath, and in many bouquets called "Fancy", as well as for the Oriental type of perfume. The absence of aromatic oils, glycerol or any other desired substance is no disadvantage for the use of lichens in cosmetics; *Cladonia rangiferina* and *Cl. sylvatica* have been recommended by parfumeurs, since they are whitish, easily dried and abundant "in open healthy places".

Miscellanea

Gums. The dyeing and paper industries have need for quantities of sizing with which to dress and stiffen silks, to print and stain calico, and to size paper. During the Napoleonic Wars, because of the French monopoly of Senegal Gum, Lord Dundonald attempted to introduce the use of lichen mucilage in place of the French product, but there is no evidence that the English market was interested. At Lyons the French appear to have successfully used lichen mucilage as a substitute for gum arabic in the fabrication of dyed materials (13). The problem has been investigated by Minford (13) who reports that Iceland Moss and some other lichens may be prepared as light-colored, transparent and high-grade gelatin, isinglass and similar gelatinous products, corresponding to those obtained from vegetable products for this purpose.

Lichens for Decorations. The use of lichens for home decorations, funeral wreaths and grave wreaths is commonly exploited in the northern countries of Europe, partly as a result of tradition and the expense of out-of-season flowers. The Cladoniaceae or Reindeer lichens lend themselves best to this purpose and are always used in center-piece table decorations in winter and in connection with Christmas ornaments. In older types of Swedish houses, where the outer or storm window can be separated from the permanent window, the space between at the base is filled with this lichen which may act partly as insulation. Dry lichens are brittle and are usually gathered and worked in the fall of the year when the air is moist; they are woven into wreaths by the poorer farming class who offer them for sale on market days at low prices. Addition of water, as for cut-flowers, does not preserve them but tends to make them moldy. Lichens can maintain themselves on hygroscopic water. The harvesting of lichens, especially *Cl. alpestris,* can be a source of considerable revenue. In 1935, 2,900 boxes (orange crate size) were exported from Norway. In 1936, 7,700 boxes were shipped, and in 1937, 12,500 boxes which yielded a revenue of 90,000 Norwegian Kroner ($1.00 = 4.90 Noar. Kr., Aug. 1947). Later shipments went only to Germany, and the Göteborgs Handels-Och Sjöfarts-Tidning (newspaper) published a story on October 12, 1946, entitled "Fjällresa Med Linné", which said that this lichen export was being used by the Germans as a source for "explosives". The Germans had an essential need for this plant also as grave decorations. The gathering of these lichens for decorations is cause for further dispute between Lapp herders and commercial harvesters. *Cladonia* species are occasionally used in table models and dioramas to represent trees.

Injury by Lichens. Lichen injury to valued stained glass windows of old cathedrals and to marble, alabaster and Florentine mosaics has been reported by various observers (13). Orchardists and silviculturists have long been interested in the relationship of lichens to trees, and many sprays, including Bordeaux mixture, caustic soda and light-boiling tar oils, have been recommended for the removal of these "unsightly if not injurious plants". Indirectly they may be the cause of economic loss by serving as shelter for harmful insects seeking cover and depositing eggs. Kaufert has noted that the bark of *Populus tremuloides* remains permanently smooth through the presence of a persistent periderm, but that if injured by fungi, lichens or mechanical injury the bark may be stimulated to develop rough fissures. In studying the influence of *Usnea* species upon trees in South Africa, Phillips (13) concluded that in this case the lichen is definitely detrimental in that its fungal component is parasitic upon tissue external or internal to the cork cambium. Vigorous crowns as well as defective ones may be infected. Since the lichen cannot develop luxuriantly under the conditions obtaining in undisturbed high forests, he recommended that the forest canopy be preserved as a means of inhibiting the rampant growth of this lichen. Wellborn (13) suggested that some leaf spots of the coffee plant may be caused by a lichen, and the classical research of Ward (21) on *Strigula complanata* Mont. illustrates the undeniable harmful effect of a lichen ephiphyte on a crop plant. Leaf lichens are common on evergreen, deciduous trees and bushes in the subtropics and tropics, but unless the leaves of such phanerogams have a commercial application, as tea leaves, there is no economic loss involved. Foresters in some parts of Europe recommend scraping lichens from trees, but there is little experimental proof that lichens ephiphytically attached to the bark, branches and twigs of trees are the cause of damage. Howbeit, the whole problem of whether lichens injure the trees on which they are fastened cannot be solved, as Elias Fries once remarked, "by mere denial".

Dyeing Instructions for Home Use (10)

Parmelia saxatilis. The Swedish country people call this the "Dye-lichen" or "Stone-moss". It occurs abundantly on rocks and stones as rugose greybrown patches, and should be collected after rain while the air is still moist, for it is firmly attached to the stones and will crumble if removed in dry air. It is most easily separated from the stones by an ordinary table knife, and if it is to be preserved it must be carefully dried before being packed in bags or boxes. Before use it should be finely crushed. The following colors may be obtained by varying the dyeing treatment.

1) Light yellow-brown. Place one kilogram (2.2 pounds) of finely crumbled Dye-lichen in a copper kettle containing a large quantity of water. Place 250

grams* of unmordanted (raw) yarn into this solution, boiling and stirring the yarn for one-half to two hours, depending on the desired shade of color. The best method of stirring the yarn is to wind it around sticks so as to avoid cloudy or uneven dyeing. When the process is completed, the yarn should be washed thoroughly in several changes of clean water, after which it may be hung up to dry, making sure that the skein hangs freely.

2) Dark brown. The lichen is crumbled and placed in layers with wool or yarn in an iron kettle. The yarn should be wet when put down, and after addition of cool water in sufficient quantities to cover the mass, several hours should lapse before boiling. Boiling must be slow and regular with constant stirring for two to six hours. If a very dark color is desired, the yarn may be boiled again in a fresh quantity of the Dye-lichen. If the desired color is black-brown, some braziline (Brazilwood chips) should be added. If dark brown color tones are desired, best work with grey yarn. Wash as above.

3) Rusty brown.

250 grams of yarn
40 grams of alum
15 grams of tartar
2 kilograms of lichen

The yarn is mordanted in alum and a solution of tartar one-half to one hour. The lichen is boiled in a large quantity of water for one hour, after which the mordanted yarn is added and then boiled for two hours. The best method is to have the hanks strung on sticks. If the yarn is not turned over maculation will result. If a red tone is desired, the yarn should be removed from the kettle and boiled one-half hour in a solution of 30 grams of soaked madder. Wash as above.

4) Dull Brown. Use four times as much crumbled lichen as yarn by weight and soak in water one day before boiling. Then boil for one hour. Add a solution of soap to the unmordanted yarn and boil another two hours, then permit it to cool. Remove the yarn and wash as above.

Cetraria islandica. This lichen, commonly known as "Iceland Moss", grows abundantly in woods and in the mountains. It is loosely attached to the ground, and is best collected in dry weather so as to save the trouble of artificial drying before storage for winter use. Before using place it in fresh water for softening, after which it is easy to chop up. Like the Dye-lichen, it gives beautiful brown colors but in different shades, and has been found to be of value in dyeing suede, since it produces the faint pastel tints desired by the trade (19*a*).

1) Brown. The lichen is cleansed, washed and finely crumbled before being placed in a kettle, alternating layers of wool or yarn with lichen. Water is added and all is boiled half an hour. Iron vitriol should be dissolved in warm water and carefully added to the mass. This is boiled slowly, stirring constantly until it is sufficiently dark. Wash as above.

Usnea barbata. This is the Beard-lichen and occurs abundantly in woods, growing on both coniferous and foliaceous trees and wooden fences, hanging down as a light grey beard. The lichen is branched, soft and elastic, and when it is pulled out the outer crust bursts and a white horsehair-shaped inner thread is left. When collecting, this lichen should be separated from needles and twigs. It gives a fine red-yellow color.

1) Red-yellow.

250 grams of yarn
32 grams of alum
250 grams of Beard-lichen

The yarn is, as usual, mordanted with alum. Boil the Beard-lichen one hour and strain off, adding the yarn to the solution and boiling for one-half to one hour, depending upon the desired shade of color. Lighter shades are obtained by using weaker solutions.

Alectoria jubata. The color of the Horsehair-lichen is greybrown or black. It grows commonly on old coniferous trees, hanging down from the twigs in long tufts. Its branches, when pulled, do not behave as do those of the Beard-lichens, but, like that lichen, it gives a yellow-brown dye, though of a different tone.

1) Yellow. Follow the instructions as for the Beard-lichen. The darkest shade will be mellow green-yellow. By diluting the solution lighter tones of a fine cream-yellow may be obtained. Wash as above.

Notice! For obtaining lighter shades of colors the yarn must be boiled six times in weaker solutions. It is not advisable to use stronger solutions for shorter times. This rule can be generally applied in all cases.

Acknowledgments

The author is greatly indebted to Dr. G. Einar Du Rietz, Director of the Plant Science Institute, Uppsala, Sweden, for the many courtesies received as a student at that Institute; to Dr. Gunnar Degelius for advice and the generous loan of his valuable collection of books and duplicates; to Dr. Rolf Santesson of the Institute for Systematic Botany for his assistance; to Dr. Magnus Fries for the use of the Th. M. Fries Lichenological Collection; to Dr. A. H. Magnusson for the use of his library; and to the Librarian of the Carolina Rediviva, Uppsala University, for many favors. The author expresses his appreciation also to the American-Scandinavian Foundation, New York City, for the Fellowship which made it possible for him to study at the Royal University of Uppsala, Sweden from 1946–1947; and to Dr. C. W. Dodge, Missouri Botanical Garden, for his kindness in checking the final manuscript of this article.

The author is greatly indebted also to Miss Carlsson of the Uppsala Hemslöjd Association for her kindness in demonstrating the dyeing technique followed in her classes and in exhibiting materials dyed with lichen dyes. Her advice and suggestions have been incorporated in this paper. Dr. Sten Ahlner, Växtbiologista Institutionen, Uppsala, translated "Dye Instructions" for the author who acknowledges his assistance in this and many other instances.

* 1 ounce = 28.35 grams; 1 pound = .45 kilograms.

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